BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Second Quarterly Review of "Study of Planetary Orbital Imaging Sensor Support Requirements," Contract Number NAS-2-4494, IITRI, Chicago, Illinois - Case 710

DATE: May 14, 1968

FROM: B. E. Sabels

ABSTRACT

The writer attended a review of planetary orbital imaging support requirements given by the Illinois Institute of Technology at NASA - Ames on April 4, 1968. The study is limited in scope to imaging sensors, and it does not intend to propose integrated scientific payloads for specific missions. The major areas of attention are scientific exploration objectives, measurement definitions, imaging systems, and orbital constraints.

The study would benefit greatly if backup material and references for choices of parameters were given, so that the mission planner could follow the study and weigh its arguments. Indeed, it is suggested that the study be extended both in its scientific and mission planning scope, so as to be useful to NASA.

(NASA-CR-95525) SECOND QUARTERLY REVIEW OF ''STUDY OF PLANETARY ORBITAL IMAGING SENSOR SUPPORT REQUIREMENTS,'' CONTRACT NUMBER NAS2-4494, IITRI, CHICAGO, ILLINOIS (Bellcomm, Inc.) 11 p

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MEMORANDUM FOR FILE

INTRODUCTION

The Illinois Institute of Technology Research Institute, Chicago, presented the review of their orbiting sensor study on April 4, 1968, at NASA-Ames, California. The purpose of the project is to estimate the scientific support requirements for imaging sensors on spacecraft to be orbited around the Moon, Mars, Venus, Mercury and Jupiter in the 1975-1995 time frame.

The study is limited in its objectives in several ways. First, imaging sensors were chosen because it is believed that they control the support requirements of sensor payloads. Second, the study estimates support subsystems requirements and does not attempt to propose integrated scientific payloads for specific missions. Third, the study does not provide any discussion of choices of parameters or weighing of alternatives, thereby limiting the usefulness of the results.

The IITRI study focussed briefly on the major areas of attention, which are scientific exploration objectives, measurement definitions, imaging sensor systems, and orbital constraints, which all affect the experiment support requirements. Then it moved on to discuss one sample experiment, regional surface topography study on Mars by radar imaging.

This paper will briefly highlight the major areas of interest in the study. It is concluded that the limitations of the IITRI study are too severe to make the work very useful. Suggestions for modifications are given in the summary.

SCIENTIFIC EXPLORATION OBJECTIVES

The study starts out with major science questions, called goals, which are expanded into subgoals, aspects, objectives, and finally, attributes. The attributes have been analyzed to determine the applicability of imaging techniques, and relevant characteristics are compiled in attribute data sheets.

After defining measurement specifications, worth curves are established, which relate measurement specifications to measurement achievement. Thus, scientific experiments associated with the attributes are identified. As shown in Figure 1, a total of 401 experiments are identified for the four planets and the moon, which are related to 23 attributes.

This writer feels that attributes such as hydrocarbons, biochemical systems, life, and others which are presently not known to exist on the planets cannot readily be investigated by imaging systems. Rather they should be attacked by radiometry, which allows spectral scanning rather than spatial scanning and which has a spectral sensitivity superior to imaging systems. After the existence and concentration of previously unknown species are established, their distribution may be mapped by imaging systems. The same approach is presently being used on Earth, for example in the 1-3 micron IR study of rock composition and vegetation.

MEASUREMENT DEFINITION

Measurement specifications have been defined by operational and natural conditions. For example, four different Martian imaging experiments are useful for the study of surface topography (the sample experiment discussed below), which are visual, visual-stereo, radar, and radar stereo imaging. The spectral regions are 0.5-0.75 microns for visible, 1-100 cm for radar imaging. The solar elevation angle is set at 20° for visual, 80° for visual-stereo imaging.

The relation between measurement achievement and measurement specifications is portrayed by "worth curves". Examples shown are appropriate to Martian surface topography regarding visual and radar imaging, spectral regions and solar elevation angle. Further curves depict ground resolution, image size and characteristics, coverage and accuracy.

All specifications are absolute and unique, and no ranges, probabilities of validity, nor references or sources are given.

IMAGING SENSOR SYSTEMS

Imagers suggested by measurement definition and arranged in 401 science and 210 science and engineering experiments are:

- ultraviolet optical-mechanical scanners and image tube,
- visible region film cameras and TV cameras,
- infrared optical-mechanical scanners, image tubes and film cameras,
- passive microwave imagers,
- radar noncoherent and coherent imagers,
- radio,
- multispectral UV-visible-IR, radio and radar, and,
- multiband systems.

EXPERIMENT SUPPORT REQUIREMENTS

Support requirements of particular interest are listed, such as weight, volume, field of view, power, data rate, etc. For each imaging sensor, a unique set of scaling laws relate measurement specifications and orbit parameters to the support requirements. Many of the scaling laws are dependent upon the state of the art. An example is antenna density. The projected decrease in antenna density (Figure 3) anticipates the use of inflatable antennas.

The procedure for estimating experiment support requirements is as follows:

1. Select tentative orbits for each experiment.
2. Form families of experiments having similar orbits.
3. Select orbit for each family.
4. Evaluate measurement achievement for each experiment.
5. Modify and re-evaluate.
6. Specify experiment support requirements.

The primary factors influencing orbit selection are orbit lifetime, planetary distribution, image size and overlap, and solar illumination constraints.

SAMPLE EXPERIMENT

Regional surface topography of Mars is used as a sample experiment in the study. One to 100 cm radar with a 1 km ground resolution and 1000 km image size is chosen. Table 1 summarizes parameters which are defined by the wavelength of the radar selected. The relation of peak power to wavelength is shown in Figure 2.

The exponential relationship between wavelength and peak power expressed in the figure and the table appears extreme. Some considerations examined by the author support the possibility that the peak power requirements for Martian radar imagery may vary by several orders of magnitude between 10 and 1 cm wavelength, but more likcly by 2 or 3 than by 5 orders of magnitude. This follows from information compiled by Evans (1) on lunar radar cross sections in the 1000 to 1 cm wavelength range and by Barrett and Staelin (2) on attenuation of Venusian surface radar. The data from both references are summarized in Figures 4 and 5. It should be pointed out in the study which choice of atmospheric models and cross sections was made to arrive at the relationship depicted in Figure 2.

SUMMARY

The study makes an interesting attempt to analyze the complex matter of scientific exploration of planets. Apparently, it was intended to go no further than to lay out all possible facets of imaging technology without considering how best to synthesize the information into mission plans. This has been done well. However, an analysis of scientific aspects of planetary orbital study is believed to be significant only if a completely referenced discussion of scientific possibilities is given. Any reader must be put in the position to evaluate the significance of every scientific parameter, such as peak power at 1 cm wavelength. Without solid backup, a study as conducted by ITTRI is believed to be of little value to NASA because it makes very complicated questions look misleadingly simple.

It is suggested that the scope of the study be widened to include nonimaging systems (radiometers-spectrometers) and to include a realistic synthesis into flyable mission payloads for the 1975-1995 time period.

1014-BES-llf

B. E. Sabels

Attachments
- References
- Table 1
- Figures 1-5

REFERENCES

1. Evans, John V, Radar Signatures of the Planets, Annals New York Academy of Sciences, p. 190-257, 1967.

2. Barrett, A. H. and Staelin, D. H., Radio Observations of Venus and the interpretations. Space Science Res. 3, 109-135, 1964.

3. Evans, John V. and Hagtors, T. (ed.) Radar Astronomy, McGraw Hill 1968.

4. Hogg, D. C., Effective Antenna Temperatures Due to Oxygen and Water Vapor in the Atmosphere, Journal of Applied Physics, Vol. 30, No. g, p 1417 - 1419, 1958.

TABLE I

Planetary Surface Radar Specifications

According to IITRI Study

Wavelength	10 cm	1 cm	0.1 cm
antenna length (ft)	800	80	8
antenna weight (lbs)	400	40	40
peak power (KW)	3	$>10^6$	
average power (KW)	2.5	$>10^5$	
power supply volume (cu. ft)	0.5	$>10^5$	
power supply weight (lbs)	20	>100	$>10^4$
radar volume (cu. ft)	50	15	10^4
radar weight (lbs)	500	200	$>10^5$

		Surface Elevations	Layering	Contacts	Structure of Features	Surface Topography	Surface Appearance	Surface Winds	Topographic Changes	Surf. Thermal Anomalies	Atmos. Thermal Anomalies	Global Cloud Coverage	Convective Cells	Cloud Formation	Precipitation Rate	Thunderstorms	Cyclone Formations	Surf. Atmos. Transfer	Radio Bursts	Auroras	Animal Life	Plant Life	Biochemical Systems	Hydrocarbons	
MOON	UV			2																					2
	VIS	2	1	2	6	4	4		2									2							23
	IR		1	4						3															8
	RAD	2		2	4	4	2		2																16
	μ									3															3
	RF																								
	MB		1	2						3														1	7
MERCURY	UV			3																					3
	VIS	2	1	3	9	6	6	2	2									2							33
	IR			6						3															9
	RAD	2	1	3	6	6	3		2																23
	μ									3															3
	RF																								
	MB		1	3						3														1	8
MARS	UV											1	2	1											4
	VIS	2	1	3	9	6	12	2	2			1	2	1			2	2		2	3	3			53
	IR			6						3	2	2	4	2			4	1							24
	RAD	2	1	3	6	6	3		2						1										24
	μ									3	2														5
	RF															2									2
	MB		1	3						3	2	1		1			2				1	1	1	1	17
VENUS	UV											1	2	1											4
	VIS											1	2	1			2			2					8
	IR										2	2	4	2			4	1							15
	RAD	2	1	3	6	6	3		2						1						2	1			27
	μ									3	2		4					1							10
	RF															2									2
	MB		1							3	2	1		1			2							1	11
JUPITER	UV											1	2	1											4
	VIS											1	2	1			2			2					8
	IR										2	2	4	2			4	1							15
	RAD	2		1	2	2	1		2						1										11
	μ									1	2		4					1							8
	RF															2			1						3
	MB		1								2	1		1			2						1		8

FIGURE 1 - SCIENTIFIC IMAGING EXPERIMENTS

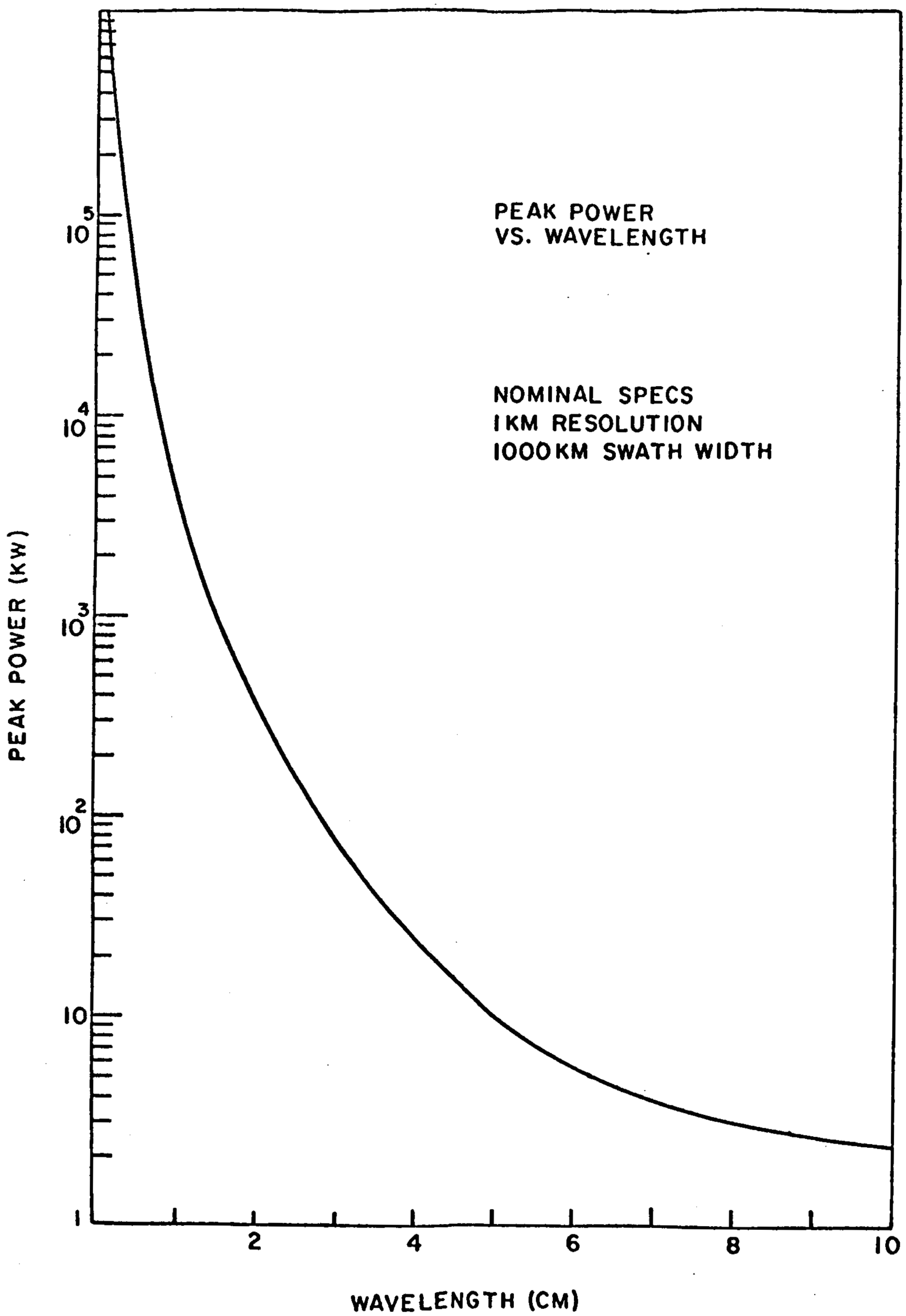
PEAK POWER
VS. WAVELENGTH
NOMINAL SPECS
1 KM RESOLUTION
1000 KM SWATH WIDTH
PEAK POWER (KW)
10^5
10^4
10^3
10^2
10
1
2
4
6
8
10
WAVELENGTH (CM)

FIGURE 2

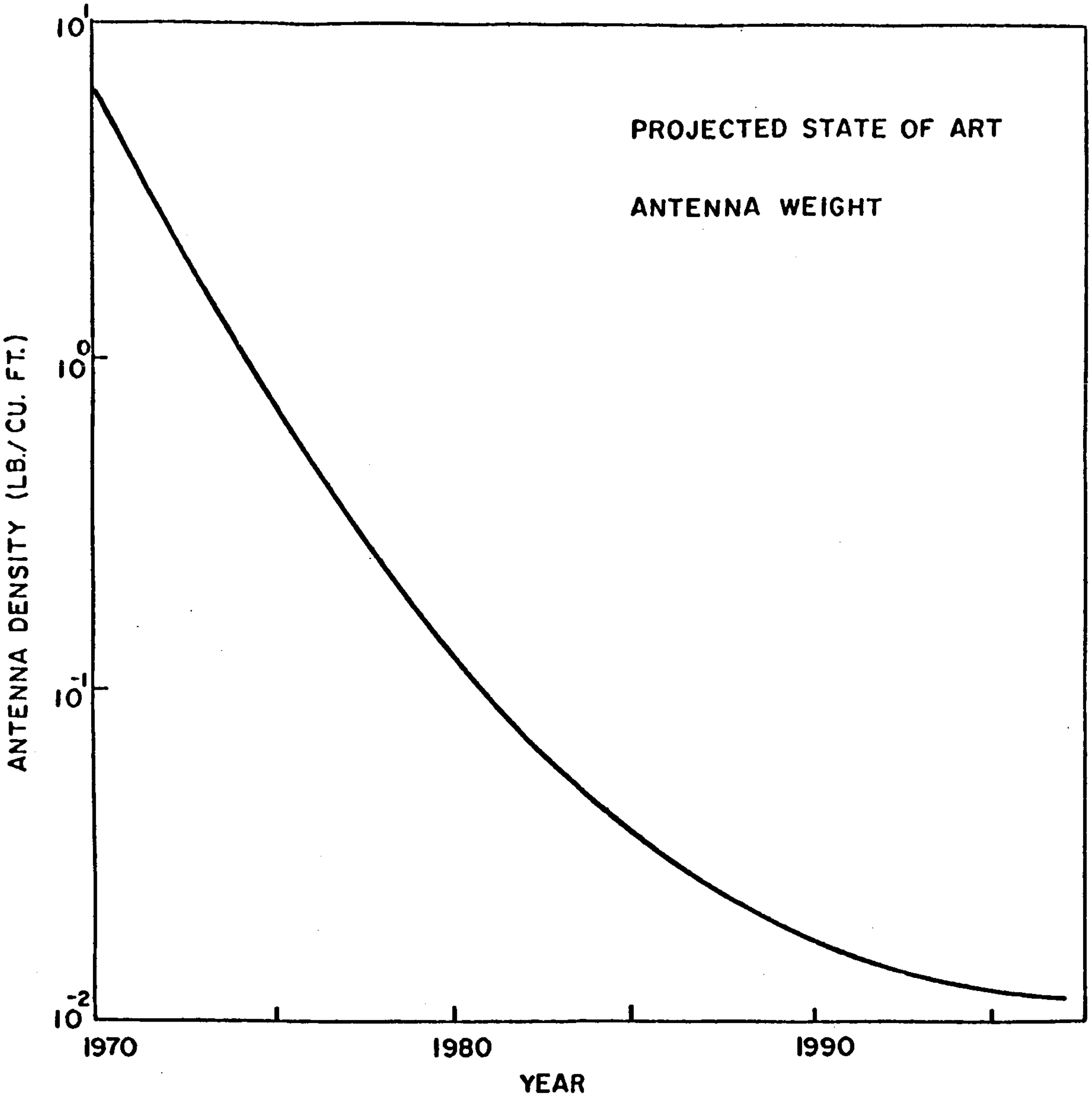
PROJECTED STATE OF ART
ANTENNA WEIGHT
ANTENNA DENSITY (LB./CU. FT.)
10^1
10^0
10^-1
10^-2
1970
1980
1990
YEAR

FIGURE 3

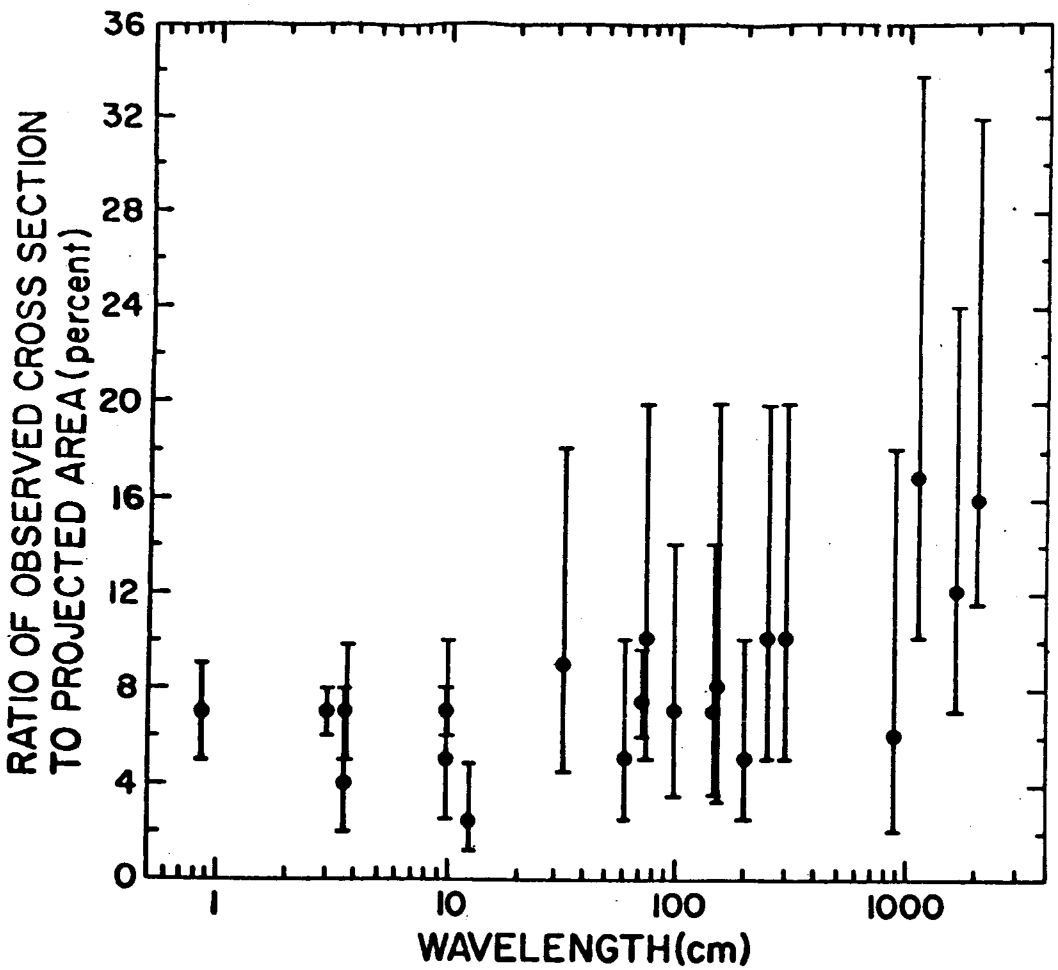

FIGURE 4 - THE PUBLISHED VALUES FOR THE CROSS SECTION OF THE MOON AS A FUNCTION OF WAVELENGTH. THESE VALUES ARE EXPRESSED AS A PERCENTAGE OF THE TOTAL PROJECTED AREA (πr^2) OF THE MOON. (EVANS, REF. 1)

Model No.	Model	Surface Pressure or Prime Constituent Density	Wavelength 3 cm attenuation (db)	Wavelength 12 cm attenuation (db)
1 (a)	$CO_2 - N_2$	300 atm	3.0	0.19
(b)	(Lapse rate = 4.86°K/km)	1000 atm	33	2.1
2 (a)	$CO_2 - N_2$	100 atm	0.58	0.04
(b)	(Lapse rate = 7.0°K/km)	300 atm	5.2	0.32
3 (a)	Dust $\epsilon_i/\epsilon_r = 0.01$	10 g/m^3	1.6	4.05
(b)	(pure abs.)	100 g/m^3	16	0.40
4 (a)	Dust, $D \leq 3$ mm	10 g/m^3	0.05	—
(b)	(scattering)	100 g/m^3	0.50	—
5 (a)	Dust, $D \leq 0.6$ mm	10 g/m^3	0.07	—
(b)	(scattering)	100 g/m^3	0.75	—
6 (a)	Cloud	0.1 g/m^3	0.61	0.15
(b)	$(\tau \sim \nu)$	1.0 g/m^3	6.1	1.55
7 (a)	Cloud	$K = 1.94 \times 10^{-6}$	0.34	0.02
(b)	$(\tau \sim K\nu^2)$	$K = 5.55 \times 10^{-6}$	0.97	0.06
8 (a)	Cloud	2 atm	5.1	0.32
(b)	(H_2O)	20 atm	330	20.6

FIGURE 5 - VALUES OF ONE-WAY ATTENUATION AT WAVELENGTHS OF 3 CM AND 12 CM FOR TRANSMISSION THROUGH THE ATMOSPHERE OF VENUS FOR VARIOUS MODELS (AFTER BARRETT AND STAELIN, 1964)

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